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THE ACHIEVEMENT OF SPACE: VALUES AND DIRECTIONS

Introduction

My association with aeronautics and space exploration has not, by astronomical time, been long, but it has spanned the whole of my adult life. I have shared in the rare privilege and opportunity of not only witnessing, but participating in the vast and bewildering changes that have moved these fields in a short twenty-five years. From the P-38 to Apollo, or from Mount Palomar to Mariner, the distance traversed by the mind of man requires new yardsticks. We seem to have moved toward a new sense of human capabilities, where imagination alone, and not technology or environment, is the limiting factor. It has been an exciting period -- and the outlines of the foreseeable future are already sketched in designs that arouse astonishment and even awe.

The change and rate of change in the aeronautic and space capability of the nation and the world is almost inevitably described in terms of the machines that reflect the technological advances or breakthroughs. But the machines are designed, built, tested, and operated by men, and it is men who, at the bench or at the desk, are responsible for the new product of these advances. That new product is knowledge, which, when directed and integrated and focused through the lens of man's mind, becomes power. What kind of men, working to what ends and under what conditions, have brought us so rapidly to the present from a recent past that already looks a century old?

The man in whose honor this lecture is given, Dr. Robert H. Goddard, was one. Another of these men, who made great contributions to the development for scientific and useful purposes of the new technology that Dr. Goddard brought into being, was Dr. Hugh L. Dryden. Both understood that their work was a beginning and door to the future, and both recognized that the greatest values were not to be found in the scientific and engineering achievements per se but would reside in the uses to which these would be put by the restless and creative minds that could grasp their fullest implications.

The history of NASA reflects much of Dr. Dryden's understanding of how progress can be made and what the conditions are that produce effective responses to the challenges being faced. A pivotal concept that has guided NASA administration has been that of the relation of the research and development project to the many rapidly growing disciplines of science and technology. A project serves a larger purpose than its own defined immediate ends. A project is a disciplined and organized effort directed to a specific objective; one of its principal characteristics is that it has a schedule. As such, a project provides a creative and driving force in the total advancement of science, engineering, and technology. A project generates demands upon these disciplines, requiring that problems be solved. These demands in turn generate a momentum that, in the long run, creates disciplinary values that transcend the return from the successful achievement of the project itself.

The translation of this concept into the practical realities of productive research and development requires what may be looked upon as a new, or at least a very rare, dimension of human effort. The increased knowledge and capability in many fields is permitting man to conduct major experiments and explore whole regions of the universe, but only when all disciplines are appropriately considered and weighed. This, then, is the dichotomy: the requirement for increased detailed knowledge on the one hand and better correlation of many disciplines on the other. The new age is demanding a quality of "wholeness", or entity, in the men who lead it. Dr. Dryden is perhaps the archetype of that "whole" man, who could integrate the disciplines of science, technology, and administration into an important pattern of major -- and measured -- decisions.

Project Planning

As understood by Dr. Dryden, scientific and technological progress is accelerated by the selection of suitable specific projects. A project may involve the laboratory testing of a new type of power supply, an advanced propulsion system, or an electronic navigation system for long-duration flights. Other projects require flight missions to gather newly sought scientific data or to develop operational systems. In any event, a project will inevitably satisfy a variety of goals, and the selection process must weigh the relative values of the various project alternatives. I will return to this selection process in the latter part of this paper.

The character of a project is familiar to all. It starts with an imaginative idea and the inner drive to perfect and test this idea. Some of the ideas of Dr. Goddard were expressed in a paper entitled, "A Method of Reaching Extreme Altitudes," which was published by the Smithsonian Institute in 1919. The first flight occurred 40 years ago tomorrow, on March 16, 1926,

on a farm in Auburn, Massachusetts, when a rocket flew to an altitude of 41 feet and traveled a distance of 184 feet. During the intervening seven years, I am certain many approaches were investigated, many designs discarded, and considerable time spent justifying the value of the project to the skeptics of the day.

Today the groundwork has been laid by Dr. Goddard and those who followed, but the general character of each project is similar. A concept leads to detailed study and analysis. Then experimental equipment is designed, built, and tested. When practice and theory are reasonably close, flight hardware can be designed. Then sufficient equipment must be fabricated for qualification testing in the anticipated space environment, flight operations must be planned in depth, and finally the space vehicle is launched and placed in operation. But of course this is not the final aspect of the project, for data is received from space that either correlates with theory, or, when different, causes the theory to be re-examined.

The project team is composed of many skills and varies in number of personnel as the project advances from concept to design, to test, and actual operation. From project initiation to flight is seldom less than four to five years, and for major projects like Apollo will take eight to ten years. The number of people increase slowly during the conceptual phase and preliminary design phase, and reaches a maximum during the design, fabrication, and ground test phase. As the chart (Figure 1) shows, the number of people have decreased substantially by the time the first flight occurs. The Apollo project is now at its peak level of some 300,000 people. By this time next year, when we are preparing for the first Apollo Saturn V launching, it is estimated that the personnel will be reduced to about 200,000.

When I state categorically that there will be a certain number of people on a project, I am assuming near excellent planning and leadership. We know on the basis of past experience that unexpected difficulties can develop that require additional manpower or longer time, or both.

The manpower required for the project is then altered in comparison with the original estimate as shown on this second chart (Figure 2). In research and development, costs are a virtually direct function of manpower; cost increases are, therefore, the result of more people being required for the same task or else the same number of people for a longer period.

One of the most visible indicators of project performance is the schedule, and since the total cost is related to the project duration, schedule charts are reviewed at all levels of NASA in varying degrees of detail. At monthly status reviews held by top management of the agency there is only time to check the estimated launch data for each project, with detailed reviews reserved for special problem cases. The estimated launch date is plotted month by month and the ability to hold this date is an important measure of the project leadership. Ideally, the launch date remains constant and the launch occurs according to plan, as shown by the solid curve on the chart (Figure 3). Oftentimes there is a trend away from the ideal, with the launch forecast slipping each month. Each project is composed of thousands of individual tasks, some conducted in series, some in parallel, so that the bases for schedule estimates are usually determined by digital computers. However, the work is conducted by man, and when difficulties develop, the project leaders must either deploy additional manpower to the problem areas or make changes in the total project plan, or accept delay. Consequently, project management is dynamic, with difficult decisions the rule and not the exception.

Let me emphasize that technical performance can be degraded under too great pressure of time and cost. At times, this effect may be secondary, but primary technical and scientific objectives must be met in spite of delays. Here again, the judgment of the management team is put to the test, since these matters are seldom black or white.

Project objectives are degraded when feasibility assessments are too optimistic or when schedule and resource processes force compromise. A project plan represents the management's judgment of the possible and the probable, balancing the risks of over-caution and pedestrian accomplishment with the omnipresent risk of over-optimism that may lead to failure.

Since aeronautical and space projects represent substantial investments and are of major national importance, NASA has taken management action to improve the accuracy of its plans and, as a consequence, to minimize risk. The project phases that I have previously described have been more precisely defined and our procurement actions have been related to these phases.

First, we must reach a determination that a specific mission objective is both valid and feasible, and then detail the alternate means of achieving that objective.

Second, from studies and analyses of these alternates, we must select the best single project approach that will fit into our program in terms of resources, schedule, and end results.

Third, a complete plan that includes system design, breadboarding of critical components, and firm cost and manpower projections must be developed and reviewed.

The last step is to implement the final plan by flight hardware development, fabrication, test and operation.

By clearly specifying the results desired in each phase, and by holding up the initiation of follow-on effort until these results have been properly reviewed, budgeting and decision-making can be greatly improved.

Administrative Considerations

The project leadership must have not only a clear understanding of the objectives to be achieved, but also their responsibility and authority must be clearly delineated. No project team can or should be given absolute authority since laws, regulations, and sound practice dictate otherwise. However, the project team must understand the boundaries and know what information is expected from them by other program and functional activities. A project team must operate within the total environment of the agency's across-the-board management structure. Detailed regulations control the entire procurement cycle; estimates of project resource requirements must be developed in accordance with agency-wide operating plan and budget procedures; status reporting must be prepared in standard formats.

As an example, the Administrator of NASA makes the contractor selections on contract awards of over \$5,000,000. Other officials of NASA have, by regulation, varying degrees of authority. Procurement decisions involve the approval of the over-all plan, the preparation of the bid request for industry, the selection of an evaluation board, the review of proposals by the board, the presentation of the board findings to NASA management, the decision to negotiate with one or more contractors, and, finally, contract definition. A summary of the procedures and authority for these procurement actions are shown in Figure 4. I will not discuss the individual actions, but must stress the importance of keeping procedures of this type simple and straightforward. Secondly, each member of the organization must recognize that their actions are time-critical and must expedite the action even though not directly responsible for the particular project.

The manager of a particular project requires a variety of information. He must keep posted on many schedules in addition to launch dates. He must follow design releases, factory shipments, environmental tests, static tests, and facility construction. He must have data on the spacecraft and launch

vehicle configurations to insure electrical, hydraulic, and mechanical compatibility between the two. Spacecraft tend to become heavier as designs are changed and he must keep the weight-lifting capability of the launch vehicle above the weight of the spacecraft. He must have detailed information on the launch and orbital operations to advise the range and the world tracking and data acquisition network of the project requirements. He must keep his cost and budget current so that his yearly obligations remain within authorization, and his total run-out costs within total budget constraints. Most important, he must be certain that real and potential technological problems are receiving adequate attention. Data for these purposes take many forms, i.e., number and duration of engine firings without instability or other difficulty, angular drift of a gyro platform, component failures of an electronic circuit undergoing environmental test, vibration modes of a launch vehicle structure in free suspension.

Under the topic of project management and information, there are several points that can be made strongly. First is that all information used in the decision-making process must be the same at each level where the decisions are being carried out. This can only hold true if those who generate the data and those who use it have mutual confidence and trust both in the data's accuracy and in the use to which the information will be put. Standardized contractor reports are often the raw inputs of such an information system, but we have learned to distill and present management information on a regular and meaningful basis that provides the opportunity for effective monitoring, review, and decision-making at every level within the total organization. A critical lesson that has been learned is that there must be room for management judgment when using the system, and a means of focusing on only key issues rather than upon masses of raw data. Another point that can be made is that only useful information needs to be generated; the Apollo Data Management System, for example, by carefully reviewing the use to which the generated information is put, has been able to reduce the output by 32%.

Finally, there is still no substitute for human competence, just as there was no substitute when Dr. Goddard launched his first rocket. There must be competence at all levels of the government-industry-university operation. Specifically, the project management team in government must have within it individuals with skills matching the jobs to be accomplished. A project team must have all the scientific, engineering, and administrative capabilities required to make the decisions appropriate to the responsibility assigned. Projects are managed from NASA centers, not Headquarters, with this requirement in

mind. Although over 90% of NASA's budget covers contractor activity, a reasonable proportion of in-house activity within the Centers must be focused on challenging scientific and technical matters to sharpen our management competence as well as to produce significant results.

Present Experience

Each NASA project has primary and secondary objectives. A mission is 100% successful when all primary objectives are achieved and is a failure (0%) unless all primaries are achieved. There are no partial successes in this scoring. It can be seen from Figure 5 that the percentage of success has risen from zero in 1958, when four failures occurred, to 80-85% during the last three years. Mission success is reviewed on a cumulative basis at the monthly top management status reviews. Last year's record, shown in Figure 6, was 23 successes out of 28 attempts, or 82%. The individual projects are listed along the bottom of the plot in the order in which they were launched. It is important to recognize that the number attempted, 28, was less than the number planned for 1965, because of schedule delays. Thirty-five launches had originally been planned for 1965. However, we were gratified that the Gemini program had planned four manned flights and actually improved on the schedule, thereby permitting the launching of five flights, including the originally unscheduled rendezvous of Gemini 6 with Gemini 7 last December.

We are learning to conduct ground and flight missions successfully and on schedule and within cost. This effort in the past eight years has broadened our understanding of the universe and provided new technology that is already finding its way into important applications. We have increased our understanding of meteorology and world-wide weather patterns, the composition of the upper atmosphere and its relation to solar events, the variation in the magnetic fields and radiation belts about the earth, the activity of the sun and the manner in which radiation is propagated from the sun, the topography of the moon, the temperature of Venus, and the atmospheric and surface conditions of Mars, by making measurements not possible on earth. We have developed new rocket motors, new power sources, new materials, special instruments, new methods of navigation and control, improved world-wide tracking and data processing. These technologies are required for the continuing scientific investigation in space and also are directly applicable to a host of new systems, including satellites for weather forecasting, communications, navigation, and traffic control. It is not the purpose of this paper to describe in detail these results but rather to discuss what we have learned from the management of these endeavors.

Management is the business of reviewing data, considering alternatives, and making decisions. It is here that the space program experience has something to offer in the nature of a lesson, for we have been, in the largest sense, witnessing not only the execution of a successful research and development program, but at the same time, the growth of an organization under near-laboratory conditions. The management experiment is, of course, delicate; the very process of observing it will affect the results. And this is particularly true when the observer is part of the experiment itself. However, there are several useful generalizations that have solid support in the history and experience of the space program, and these may be of more enduring value -- if understood and applied -- than many of the transient accomplishments usually associated with research and development activities. For it is to man that we finally come in any analysis of values and it is by man that any achievement is judged. It is, therefore, for him to examine with some care the interaction of men and objectives in the conduct of a guided enterprise.

Since the best lessons are taught by practice, rather than theory, and since mistakes are often the surest guides to correction, case studies are useful tools of communication. The NASA experience is far from complete, and there are assuredly many imperfections in the arts of management yet to be revealed. Several hard fundamentals, however, have been learned through trial and error or transfer from parallel undertakings. Ultimately, effective execution of a total research and development program, made up of many component projects that are supported by, and feed into, the forward-flowing stream of science and technology, must rest upon the successful synthesis of the parallel disciplines of science, engineering, technology, and administration and its translation into correct operating decisions.

There is no difficulty in extracting from the dynamic and rapidly evolving program of aeronautic and space exploration a catalog of problems and, through application of hindsight, a complementary list of textbook solutions. Unfortunately, history is not repetitive. The quality of "sameness" that permits industrial mass production and that is one of the great national strengths is anathema to research and development. The difficulty lies in categorizing past problems meaningfully to permit non-rota learning. Under the broad title of management discipline, the NASA problem-and-solution experience can be viewed as providing insights into planning, organization, information, and the role of people in the research and development process.

Six representative project problems, not all of which have been solved as of this moment, are good examples of the kind of experience from which useful management generalizations can be drawn.

Structural Dynamics Early in the program, a launch vehicle-spacecraft combination exploded 60 seconds after lift-off. Substantial photographic and technological data were available for the ensuing investigation that was conducted jointly by NASA and DOD. The propulsion system appeared normal, and since the accident occurred near maximum dynamic pressure, it was felt that aerodynamic loading contributed to the failure. Static forces appeared insufficient to cause the damage; consequently, the flight was simulated mathematically, taking into account all known dynamic effects including structural bending, control system performance, and estimated atmospheric turbulence. From this investigation, it appeared that the launch vehicle adapter section had insufficient rigidity. The adapter was strengthened and all later flights were successful.

Propulsion A reliable propulsion system was modified for multiple restart in space. The modified system was tested in special ground facilities that simulated high altitude but not the true space environment. The results appeared satisfactory, but the system failed catastrophically during the first test in space. Telemetry confirmed the failure, but did not reveal the cause. Most of the changes made in the original and reliable system have been eliminated and the propulsion system has successfully undergone extensive ground testing.

Switching In one important space mission, certain television equipment could not be actuated at the critical time. The telemetry data was insufficient to pinpoint the exact cause, although several failure modes were hypothesized. Post-flight review of the records of the pre-launch tests indicated that incipient weaknesses in the spacecraft circuitry would not have been evident under the test procedures actually employed. Design changes were made in the next spacecraft to remedy each of the suspected failure modes and a program of ground testing was instituted which focused closer attention to overall systems operation under simulated mission conditions. The modified spacecraft successfully completed these more rigorous ground tests and subsequently made a highly successful space flight.

Horizon Sensor. The performance of one of NASA's large scientific satellites which required an active three-axis stabilization system was seriously degraded by the unexpected sensitivity of its earth-seeking horizon scanners to cold clouds. The control system for this spacecraft was designed to scan the earth's infra-red spectrum and to then track the earth's horizon as determined by the difference between the cold of outer space and the heat of the earth. Shortly after launch, it was discovered that high altitude cold clouds distorted the infra-red spectrum and caused the spacecraft to establish and track a false horizon. The encounter with cold clouds generally occurred during passes over the tropic regions. Following each encounter, the spacecraft sought to re-establish the true horizon. This resulted in an excessive usage of the stored control gas and limited the period of stabilized life-time to less than ten days. Laboratory tests have now proven that this problem can be solved by decreasing the scanner's sensitivity to cold clouds and biasing the tracking scan towards space.

Configuration Control. In the case of another major satellite project, the project team was dealing for the first time with a scientific group representing a discipline that had not been associated with space flight projects before. A spacecraft mock-up was developed with models of all the experimental hardware in their places to assure that no interface problems existed. To all appearances, the spacecraft design at that time represented an integrated whole. Seven months later, after the experimenters and engineers responsible for the various systems and subsystems had built prototype hardware and the final spacecraft structure had been built, the new prototype was assembled. We discovered that the principal scientific experiment for this flight could not be carried out in this configuration; a spacecraft structural member was interposed between the two critical elements of the experiment. Redesign, rescheduling, and new compromises between the requirements of the various subsystems will now permit the project to move forward. The absence of strict configuration control was responsible for this divergence from the initial plan.

Programming. A back-up mode in a launch vehicle guidance system was utilized when the primary mode failed. The guidance commands forced the launch vehicle off course and the range safety officer rightly destructed the system. Subsequent investigation of the guidance commands revealed an error in programming. The complex guidance equation had one term with the wrong algebraic sign. It was a simple matter to reprogram the computer for the next flight.

This list is a representative, but by no means an extensive, summary of NASA experience. From this type of experience we have concluded that:

Technical feasibility should be verified before commitment to a flight project. Oftentimes delays in the development of critical items will pace a large project and cause the costs to increase appreciably, or the item will fail in flight aborting an important mission. Both a broad advanced research and development program and phased project planning are a means of early determination of feasibility.

Design reviews must be detailed, and must be conducted at appropriate times both prior and after commitment to flight hardware. All elements of the project team must be represented. Major changes in layout should not be made between design reviews without the approval of the project manager. In this manner the configuration can be made to satisfy the requirements of the experimenters, spacecraft and launch vehicle design, and ground support operations.

Ground testing should qualify all parts and systems in the space environment. In addition, spacecraft should be tested as realistically as possible in environmental chambers, and launch vehicle stages should be static tested under sea level conditions. It is also desirable to conduct dynamic tests of the entire configuration in free suspension to determine the various bending modes.

Mission simulation is required to train the project team and to identify difficulties in programming and procedure. In preparation for manned flights, a spacecraft simulator should be available for the astronauts. This simulator should transmit and receive information from the world network and mission control center in as realistic a manner as possible in order to train both the flight and ground crews. Experience should be obtained under nominal or expected conditions, as well as under emergency conditions where back-up modes are required.

Modifications to existing reliable launch vehicles and spacecraft should be minimized and only made after careful design review and test. Modifications increase cost and often cause delays and even unexpected failures to occur.

Even when developing new launch vehicles and spacecraft such as Saturn and Apollo, it is preferable to launch the final design early. In this so-called "all-up-systems" approach, experience is gained on all components and their interaction as soon as possible. Although this approach is more subject to failure in early flights than the more conservative step-by-step approach, it is felt that there is an ultimate saving in cost and time.

It is my belief that these procedures have contributed to the mission successes of the past few years. Schedule slippages and cost over-runs have also been reduced, but are still excessive. As we obtain more experience, performance should improve through better understanding of these principles and through tighter application of these procedures.

I would like now to turn from the specifics of project management to a discussion of the groups within our society that carry out this effort. It is important to examine with care the interrelationship of the university-industry-government team.

University-Industry-Government Team

Universities, industry, and government are the institutions most commonly called upon in this country for some aspect of research and development. At the graduate school level, universities are concerned with both research and education, with research providing an opportunity to advance the science and engineering curricula. Industry is best equipped to design, fabricate, and test equipment, and in some cases to assist in its operation. When funds for research and development are appropriated by the Congress, it becomes the responsibility of the government to manage the effort and insure that value is received, whether the work is conducted by universities, industry, government, or a combination of the three. Space flight projects are of such a nature that all three institutions are usually involved, and hence their relationships become important to the success of most projects.

Universities. Since the inception of the Agency, we have followed the deliberate policy of involving academic scientists in the space program. We have found it profitable to do this for several reasons. Some of the most competent and most creative scientists are at the universities. Hence, we get from them exciting proposals for research in space. Secondly, the NASA act charges us with the responsibility for the fast and thorough dissemination of the knowledge gained in space research. The most accurate and most rapid way of spreading the knowledge and techniques gained in space research into the curricula of the universities and into the common body of national knowledge is to have professors conducting the experiments, analyzing and interpreting the data, and publishing the results. When they are involved in the program in this way, they involve their graduate students; they describe their experiments and their results to their classes; they write books; they write review articles; they serve as consultants to industrial organizations -- in brief, there is a very short, very direct, and very accurate transmission line from the source of new knowledge to places where it can be used.

The first cornerstone of our policy is to rely heavily on the individual scientist for the ideas for research to be conducted in space, for the development of the experimental hardware, for the analysis and interpretation of the data, and for the publication of the results. We do not issue a request for proposals to scientists asking them to propose to such and such a task. Rather, we maintain a continuing dialogue with the scientific community through organized official channels,

through studies conducted by the National Academy of Sciences, and through contacts with individual scientists. From this dialogue emerges the requirements for particular spacecraft to be flown on particular trajectories to accomplish the scientific objectives. We then establish a mission and notify the scientific community of the opportunity to propose experiments to be performed on the spacecraft.

What we in NASA "buy", I want to emphasize, are complete proposals by a scientist to accomplish a piece of scientific research and to publish the results from it, and not pieces of hardware to be integrated into a spacecraft. The proposal contains an estimate of the amount of data analysis that will be required, and the scientist agrees to accept responsibility to analyze, interpret, and publish the results from his experiment.

After approval of his experiment, the scientist becomes a part of a project team responsible for the over-all success of the mission; a project scientist is normally a practicing space scientist who understands both the engineering and scientific problems. The project team is responsible for the design and development of the spacecraft and for the integration of the experiments into the spacecraft. The experimenter is responsible for the design, development and delivery of the flight hardware for his experiment. This is an area in which we have had many questions and have encountered a certain amount of resistance from scientists who have not participated in space research before. These people question the need for their going through the lengthy and difficult task of developing their own flight hardware. They argue that NASA should do this for them and then give them the data after the spacecraft is launched. We have found that we do not have good results if we work this way. The scientist must be involved to see that the proper calibrations and tests are made, the proper design is followed, the proper components are used -- otherwise, we find that, while we can produce a beautiful piece of hardware without involvement by the experimenter, when the data comes back, the experimenter may not be able to understand or interpret it. He should be intimately involved in the experiment and held responsible for its performance.

The presentation of the results from an experiment and their incorporation into the curricula and general fund of knowledge varies some from mission to mission, but generally follows the following pattern. The first results are usually presented at symposia or scientific meetings about six months after launch, and the final definitive publications appear two to three years after launch. Incorporation of the results into review articles, books, and handbooks requires three to five years. If there is a need for particular data or great interest in it, all of these times may be drastically shortened. We needed data from Mariner IV on the Martian atmosphere as

soon as possible. Mariner IV was occulted by Mars in August 1966, and we were using the new information on the Martian atmosphere to aid in the planning for Voyager in late September.

In summary, we have a working hypothesis that both the academic community and the government derive new strength from the complex interrelationships of project effort; we are continuing to test this hypothesis and to experiment with variations and alternates.

Industry. We have a similar working hypothesis concerning the role of industry in the space program. A delicate and ever-changing balance must be drawn in the execution of any project between the authority and responsibility of the government project manager and that delegated through a contractual instrument to the industrial partner. In research and development, the buyer-seller relationship between government and industry is evolving toward new and cooperative arrangements that have become necessary to take full advantage of the total strength represented by the industrial competence of the nation. Many different approaches have been tried in the past and many innovations are being tried at this time; of these, the incentive contract appears well-suited to our concept of the research and development project.

The concept of an incentive contract is relatively simple; its reduction to practice is considerably more complicated. Ideally, the incentive contract represents an arrangement between the government and an industrial partner that rewards the contractor for superior performance but penalizes him for inadequate performance. Since the research and development project is essentially an attempt to solve unknown problems, it becomes difficult to establish a fair median from which to measure the quality of performance as well as the source of responsibility for that performance. There are no simple answers here. Each new project represents a whole new challenge to the administrators who are charged with organizing the procurement pattern that will support it. Indeed, there are as many incentive structures as there are development projects, and both industry and government are learning the values and limitations of these approaches. The fundamental lesson that both parties have learned is that no meaningful incentive contract can be arrived at until very clear and precise understandings as to the objectives of the assigned task have been reached. The phased project approach discussed earlier becomes an important tool in narrowing the area for misunderstanding of this aspect of the project. In turn, with clear objectives, there must be a specific delegation of project responsibility by the government to the contractor and an equivalent commitment by the contractor to meet these responsibilities.

NASA's commitment to this approach is dramatically emphasized in Figure 7. Five years ago, we had one incentive contract with industry worth about \$100,000; by the end of this year, we will have considerably more than \$4,000,000,000 worth of effort managed

under an incentive formula.

While we desire to write incentive contracts wherever possible, we do not intend to do so where such contract forms are ill-suited to the job at hand. Further, we do not intend to use a form of incentive contract which places a disproportionate share of the responsibility upon the contractor. Mistakes have been made, both by the government and by industry. However, we are working to achieve a balance of governmental and private responsibility which assures that all who participate in the space program have an opportunity to derive returns commensurate with the effectiveness of their efforts.

Our own efforts to validate the use and effectiveness of incentive contracts with respect to research and development have given us greater insight into the benefits to be derived from incentive contracts and the problem areas which they present. Incentive contracts do result in higher management attention, increase cost consciousness on the part of the contractor, promote clearer definition of requirements and better communication and understanding among all those involved with the project. On the other hand, negotiation of incentive contracts for research and development work requires deeper participation of engineers and scientists to assure that realistic technical objectives are established and that incentive provisions are drawn in a manner which will motivate the attainment of those objectives. However, we feel that the application of scientific and engineering time at the outset of a procurement makes for a better end product.

As we proceed with our contracting efforts, we will continue to study the effectiveness of incentive contracting. We will learn both from our successes and from our mistakes. And we will continue to seek the best ideas, the most daring concepts, as we develop the means for accomplishing our assigned missions with the greatest returns to the entire society that we serve.

Organization In concluding the discussion of the university-industry-government team, I would like to emphasize the importance of the individual, and the resulting importance of the framework in which he operates. The pros and cons of project and functional organizations have been debated extensively by their adherents for many years. Admittedly, neither type exists in the pure state. All facilities, personnel, and controls are never the sole responsibility of the project manager, nor has one man with no staff ever directed a large project in a matrix organization.

Having observed over 100 space projects, I believe it is inescapable that project-oriented organizations should be favored when managing these projects in both government and industry. The advocates of functional organization argue that an individual derives more satisfaction and feels more security working within a discipline-oriented group. I agree, if the objective is primarily research or advanced development, but in project work the multidisciplinary ties must be strengthened organizationally and the disciplinary ties must be inherent in the capability of the individual. Engineers, scientists, and administrators must be closely coupled day-to-day in a successful project group. Reports, specifications, and other information are essential, but in addition science, engineering, and administration can only be satisfactorily married by the close communication and respect of individuals leaving their various backgrounds and working within the framework of an effective project team. Consulting, special assignments, and definable tasks can be conducted by supporting laboratories, but the decisions must be made by a project team having a full understanding of all significant disciplines.

Further proof of the value of the individual as a data storer and communicator can be found in a comparison of Mercury and Gemini launch operations. Mercury capsules were "bought off" at the McDonnell plant after extensive testing, shipped to Cape Kennedy, stripped down, inspected, reassembled, retested, mated and launched successfully. The effort at the Cape was time-consuming but served to assure the launch crew that they understood fully the readiness status of the spacecraft. In the case of Gemini, the launch crew participates in the testing of Gemini at the McDonnell plant; then, after "by-off", both the McDonnell and government personnel proceed to the Cape. Experience has shown that this mobility of personnel provides the continuity necessary to reduce substantially preparation time for launching at Cape Kennedy with no commensurate reduction in reliability.

Future Directions

A few years back when atomic energy, automation, and computers had made a sort of cumulative impact on the general consciousness of society, there was a cynical story making the rounds. All of the scientists of the world met at an international conference and decided to build a super computer that would use all of the resources and knowledge at their disposal. When the computer was finally finished they pondered on what the first question put to it should be, and they decided on, "Is there a God?" The question was coded and fed into the machine, whereupon it whirred and flashed and gave the answer, "There is now."

I tell this story to emphasize what I believe to be true. There is both promise and warning in the future. The promise lies in man's apparent ability to find ways to do almost whatever he wills and to marshal his resources, his ingenuity, and his intellect to these ends. The warning lies in the danger that the ability to evaluate these ends may not be growing as rapidly, if at all. If we have learned to marry the disciplines of science, engineering, and administration, have we learned to establish valid goals for their pursuit.

We can see many great human needs. As we look about the world, we find poverty, hunger, and lawlessness. We find ever increasing populations serving to still further compound these needs. We find cities gradually suffocating with polluted air, and strangling under increased automotive and aircraft traffic. Outside the cities we find our fresh waters growing foul and our natural resources diminishing. We can draw an analogy to our manned spacecraft, with their limited expendables of power and water, and their environmental control systems in delicate balance. We are starting to outstrip the capability of our terrestrial spacecraft which, if we are careless, can become uninhabitable.

The real achievement in space has been the development of a new dimension of national power. That power resides in the minds of men who have both confidence and knowledge, for whom the word "impossible" does not pose a serious barrier. Many basic human needs can be satisfied directly, at least in part, by aeronautics and space activity. Travel, communications, and weather forecasting are all important ingredients of a viable planet. Other possibilities we see less clearly today, but there is the promise of improved understanding of oceanography and geology, better husbanding of natural resources, and ultimate control of the atmosphere through understanding developed from further space exploration.

Of course, much effort must be expended on non-space activities, but here it may turn out that our management experience and our documentation centers containing extensive scientific and technological information will be of longer lasting importance even than our space flight missions.

But why then also continue to look outward away from the earth in our space exploration? We can better understand the universe and consequently ourselves by investigating the moon, planets, sun, and stars. Our sun has a direct impact on conditions here on earth in ways we can better postulate as a result of the space program, but do not yet fully understand. The moon, with no atmosphere, is a treasure chest of artifacts that have been collected for eons of time. The planets have atmospheres and, though markedly different from our own, will give us greater insight into the physics of our planet. The stars, although probably not directly affecting us in our lifetime, provide a magnificent laboratory to better understand the mechanics of the universe that in turn may stimulate our thinking and generate new concepts useful to mankind.

I believe the true challenge before us is no longer how to cope with our environment--although the problems and barriers are great, they can be overcome--but how to cope with ourselves. The question is one of human will. I believe man will rise to the challenge, but this cannot be assured. President Kennedy expressed this view on October 22, 1963, at the anniversary convocation of the National Academy of Sciences:

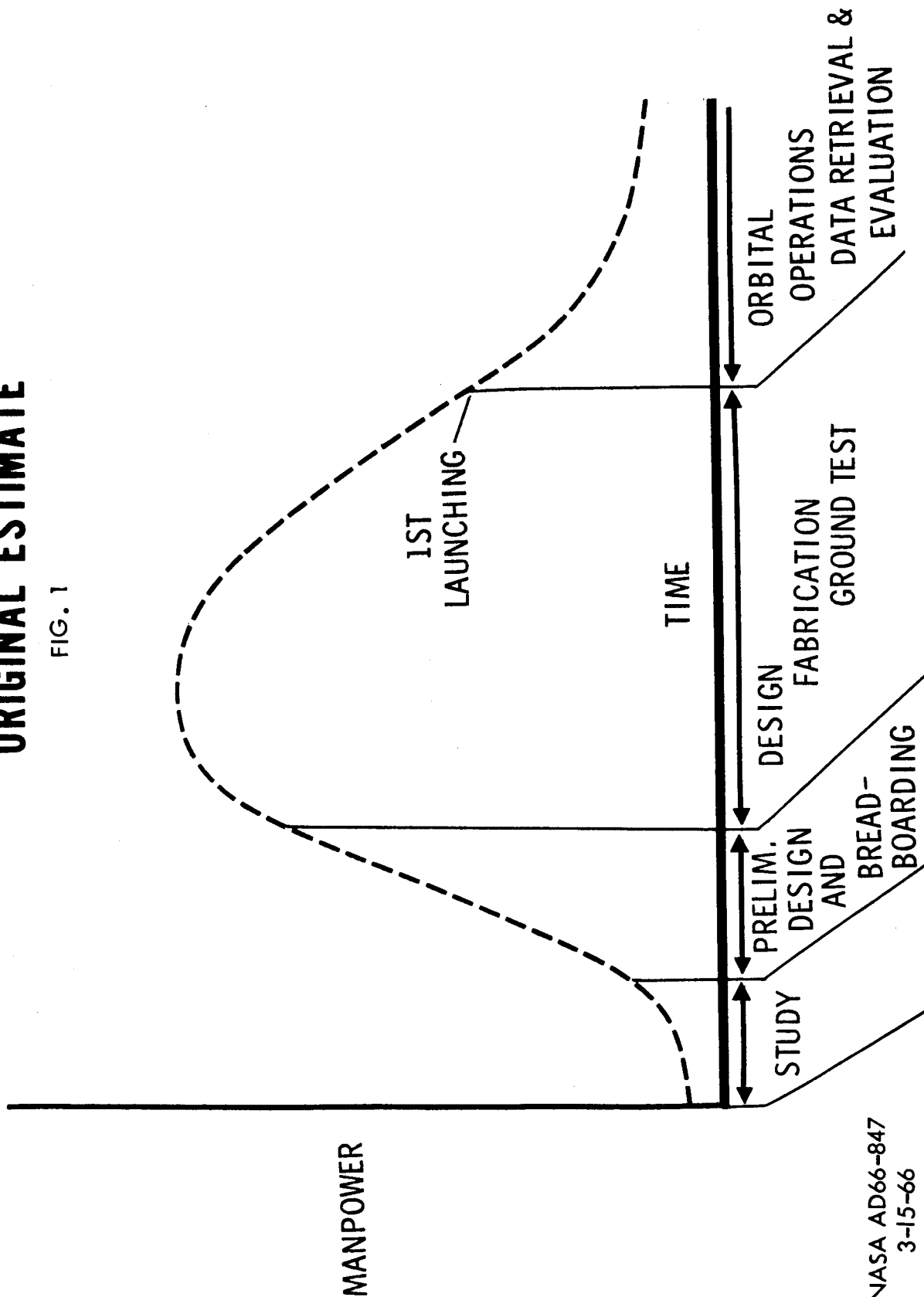
" . . . If scientific discovery has not been an unalloyed blessing, if it has conferred on mankind the power not only to create, but also to annihilate, it has at the same time provided humanity with a supreme challenge and a supreme testing. If the challenge and the testing are too much for humanity, then we are doomed. But I believe that the future can be bright, and I believe the power of science and the responsibility of science have offered mankind a new opportunity not only for intellectual growth, but for moral discipline; not only for the acquisition of knowledge, but for the strengthening of our nerve and our will."

* * * *

PROJECT MANPOWER VS. TIME

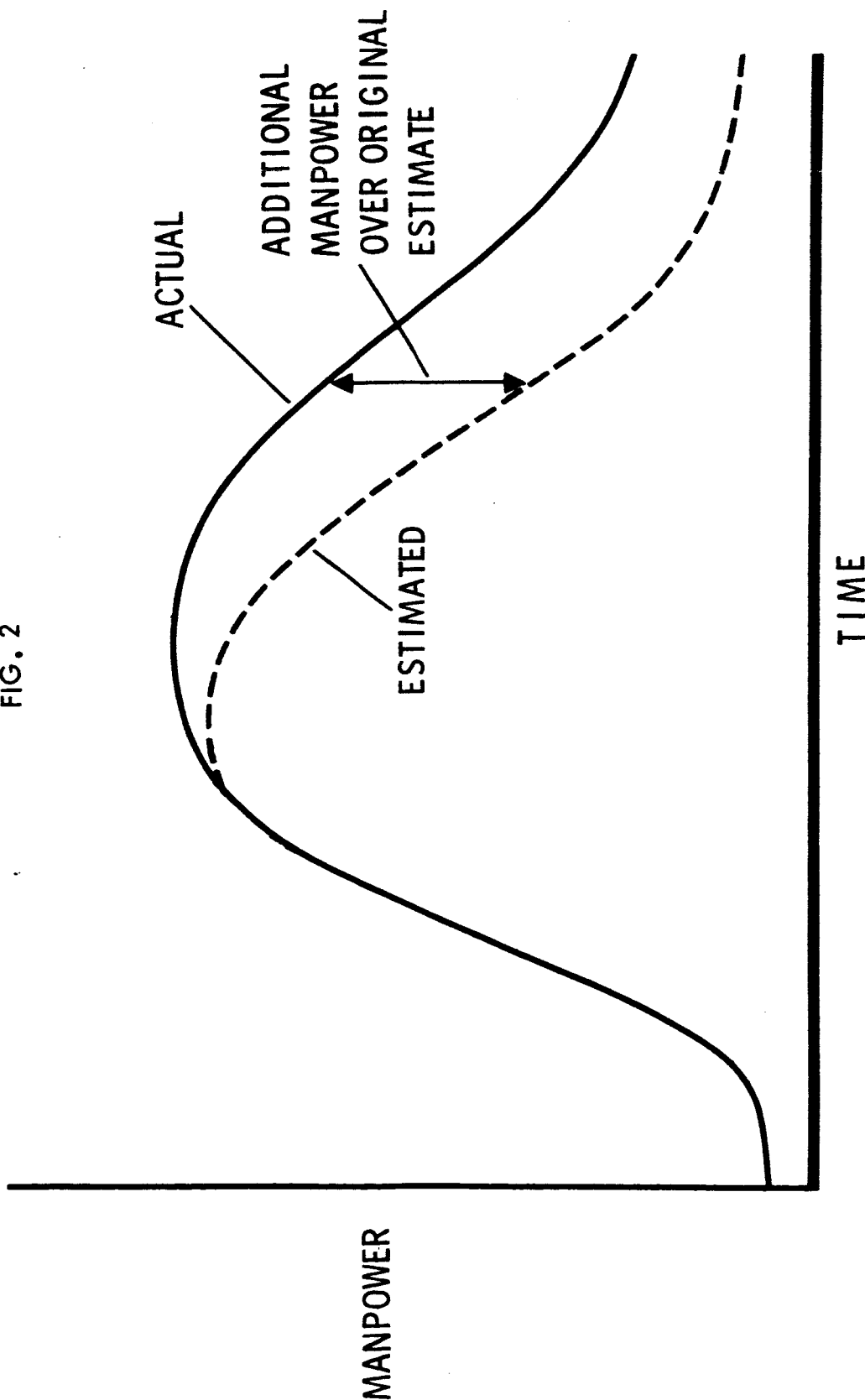
ORIGINAL ESTIMATE

FIG. 1



COMPARISON OF ACTUAL & ESTIMATED MANPOWER

FIG. 2



SCHEDULE HISTORY

Fig. 3
LAUNCH DATE TREND CHART

LAUNCH DATE AS
PERIODICALLY ESTIMATED

SOURCE (S) :

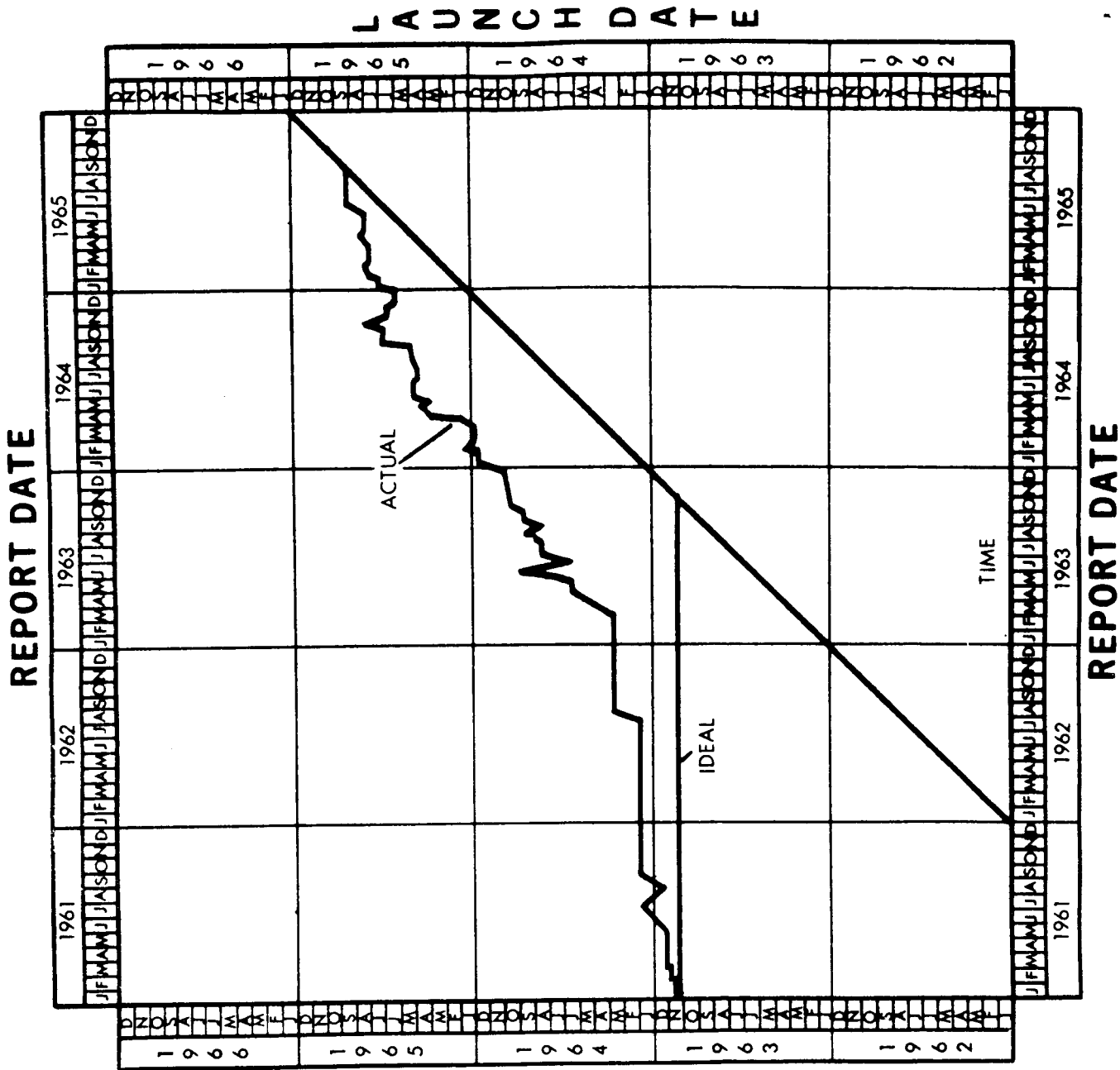
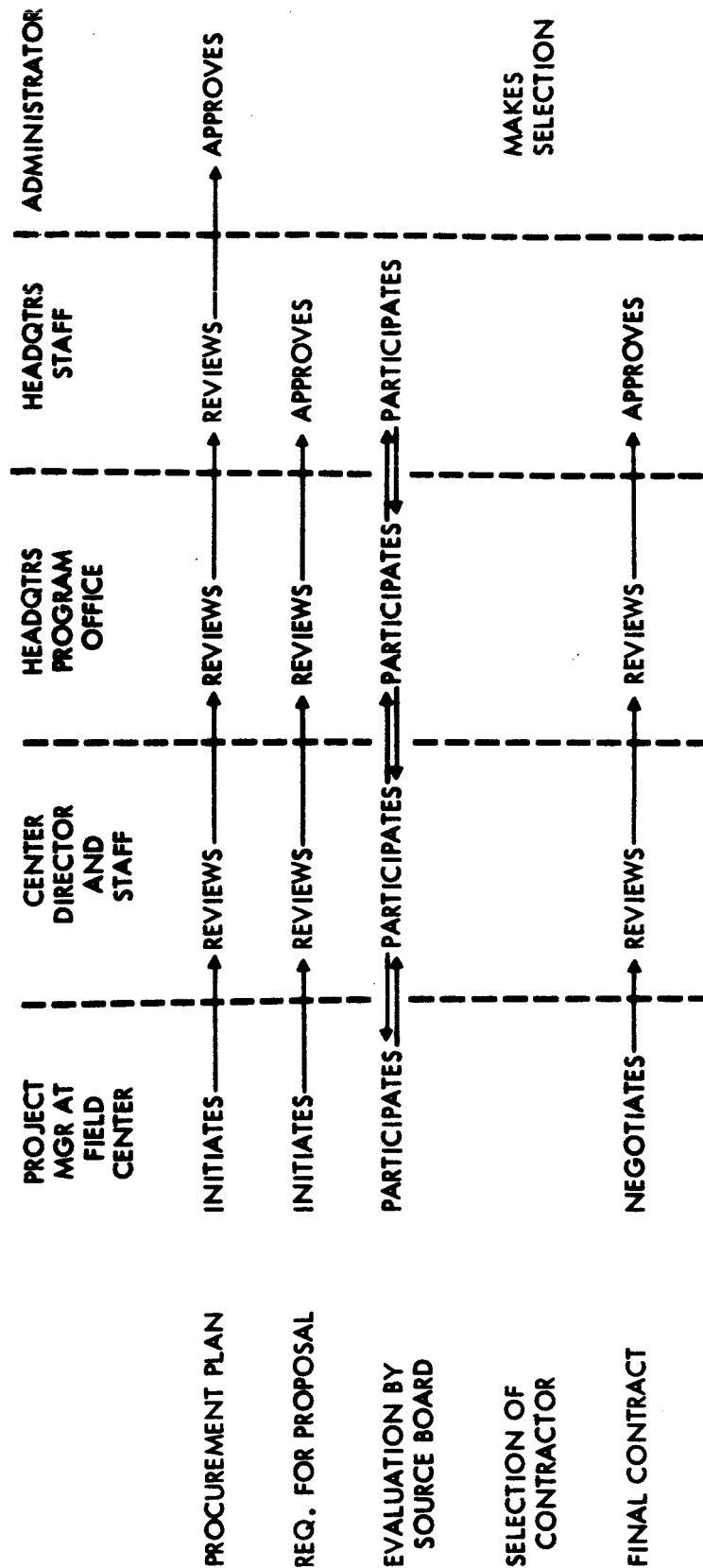


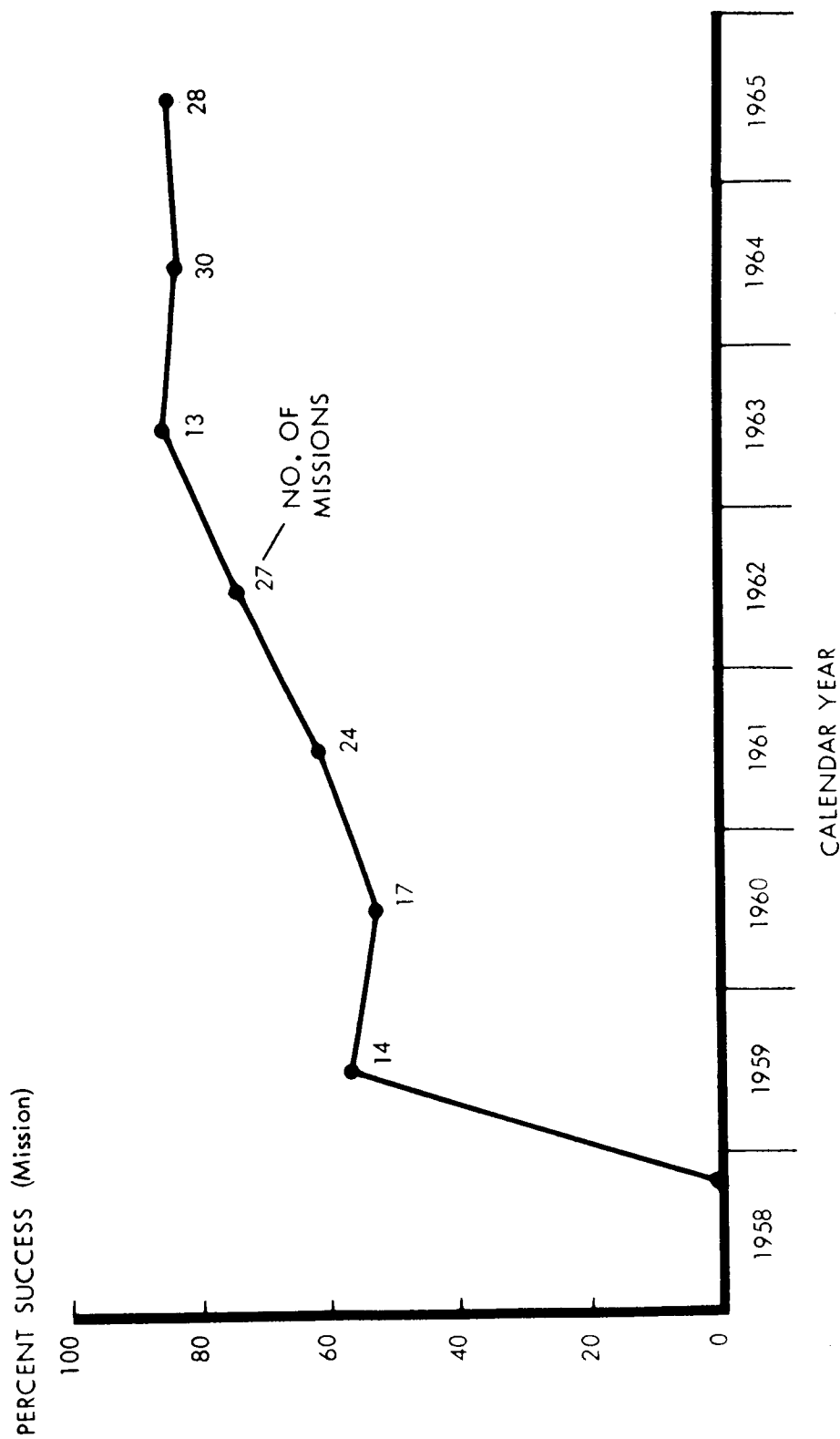
FIG. 4

PROCEDURES AND AUTHORITY FOR PROCUREMENT ACTIONS



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FIG. 5
SPACE FLIGHT RECORD

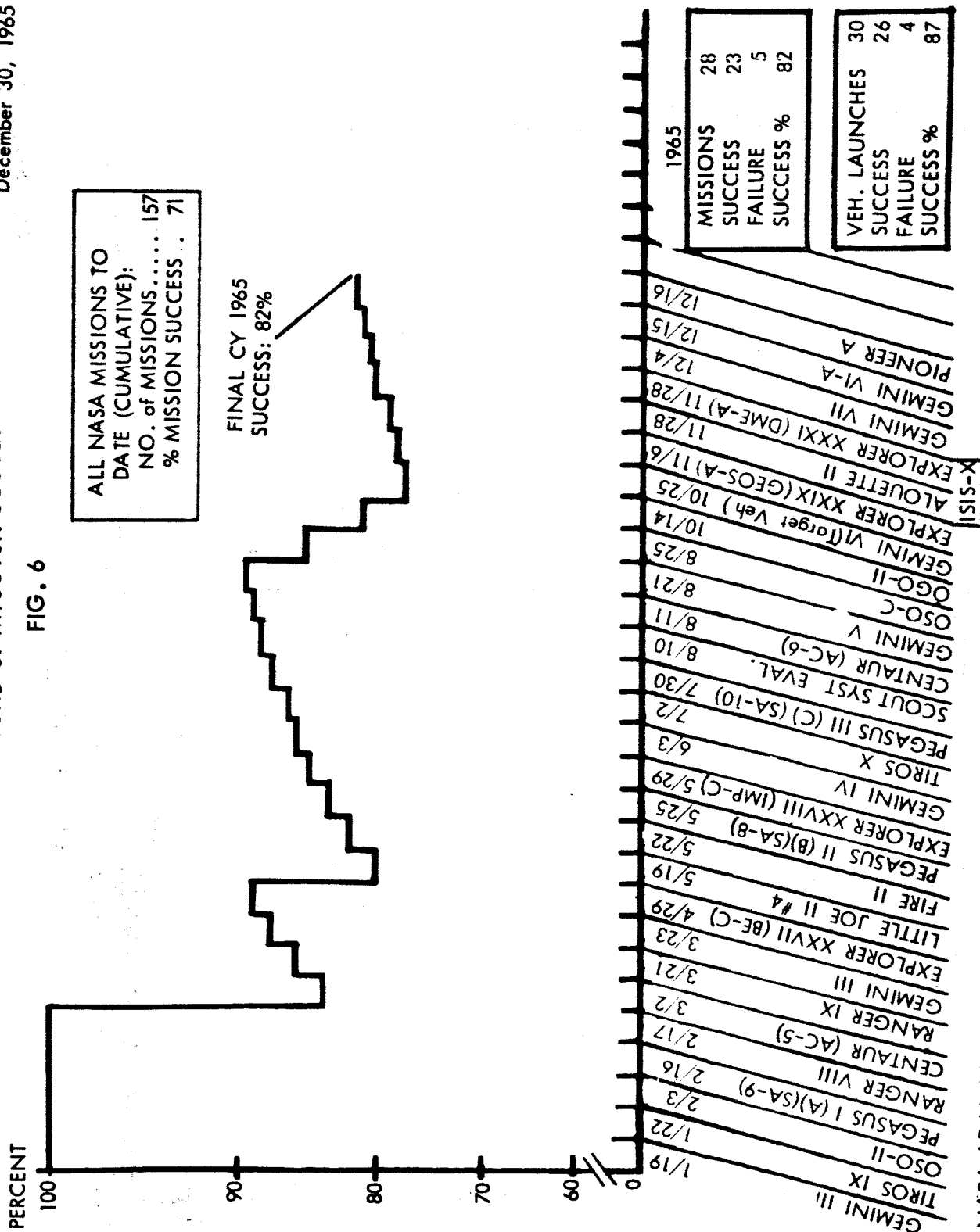


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1965 RECORD OF MISSION SUCCESS %

December 30, 1965

FIG. 6



MISSIONS	28
SUCCESS	23
FAILURE	5
SUCCESS %	82

VEH. LAUNCHES	30
SUCCESS	26
FAILURE	4
SUCCESS %	87

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Fig. 7
EXTENT OF NASA INCENTIVE CONTRACTING
(IN BILLIONS OF DOLLARS)

